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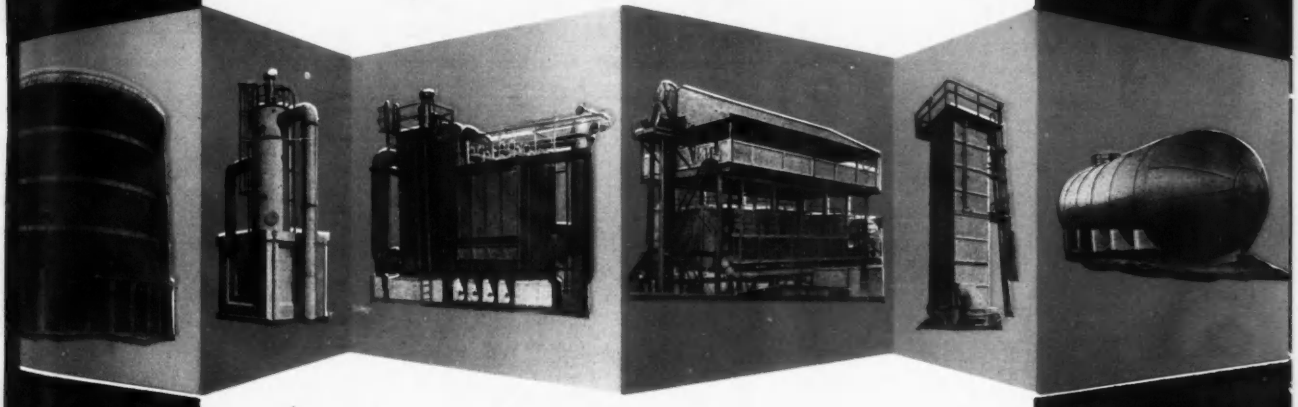

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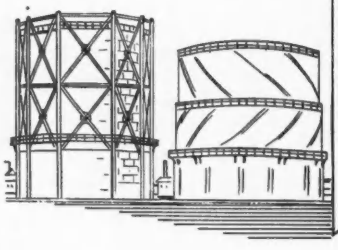

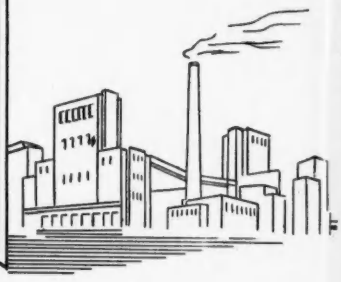

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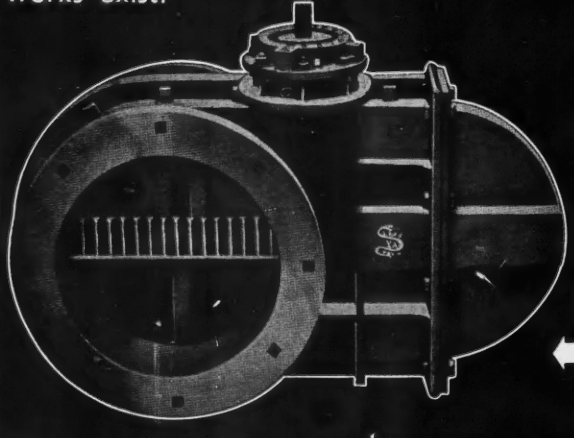

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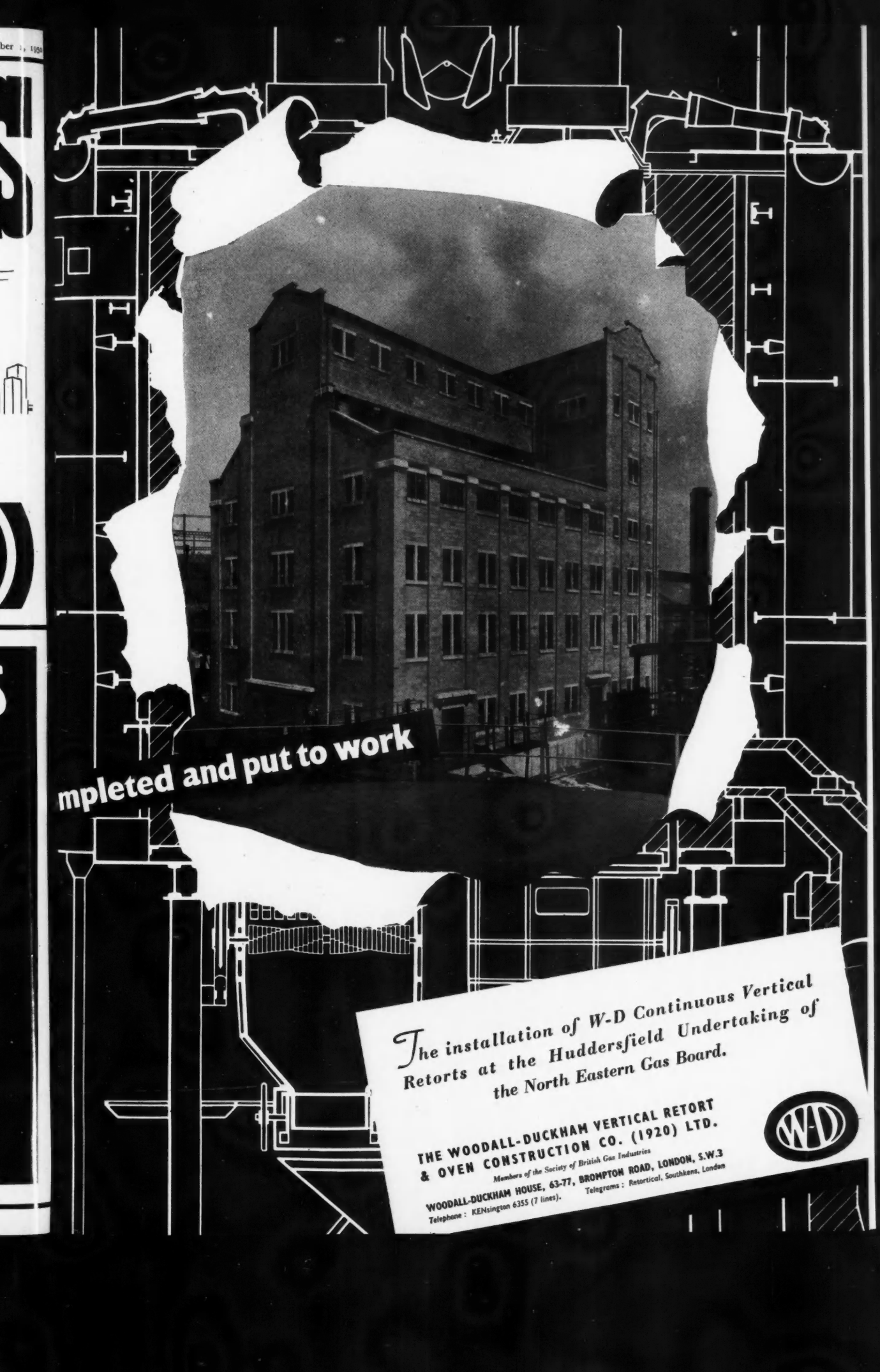
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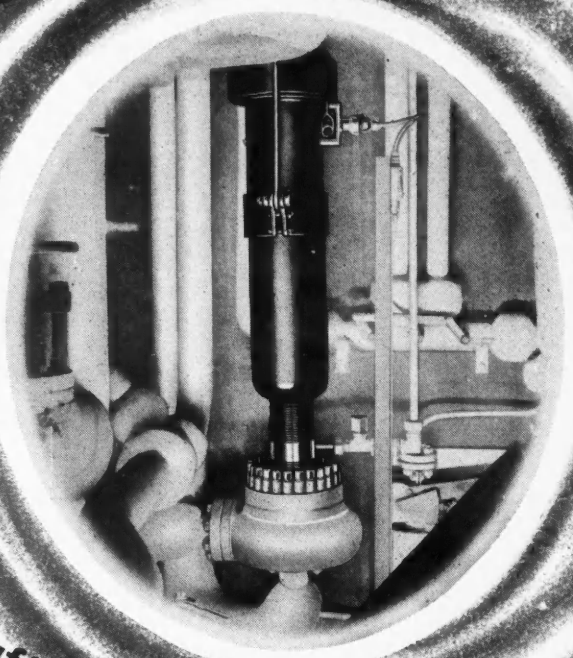

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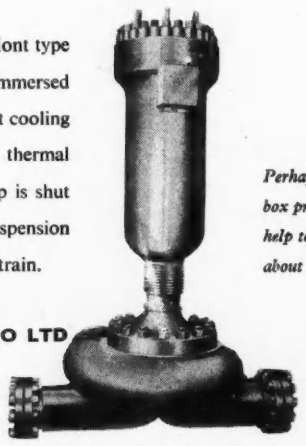

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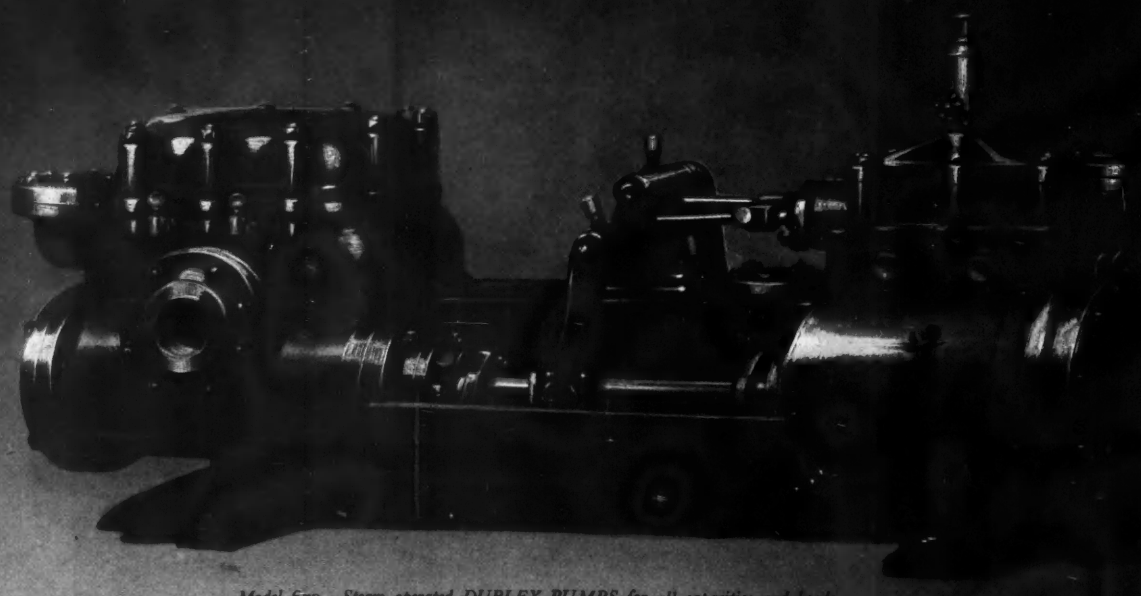

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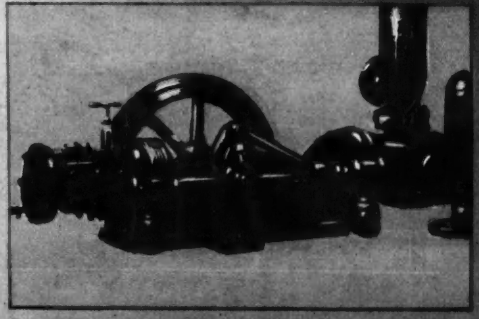

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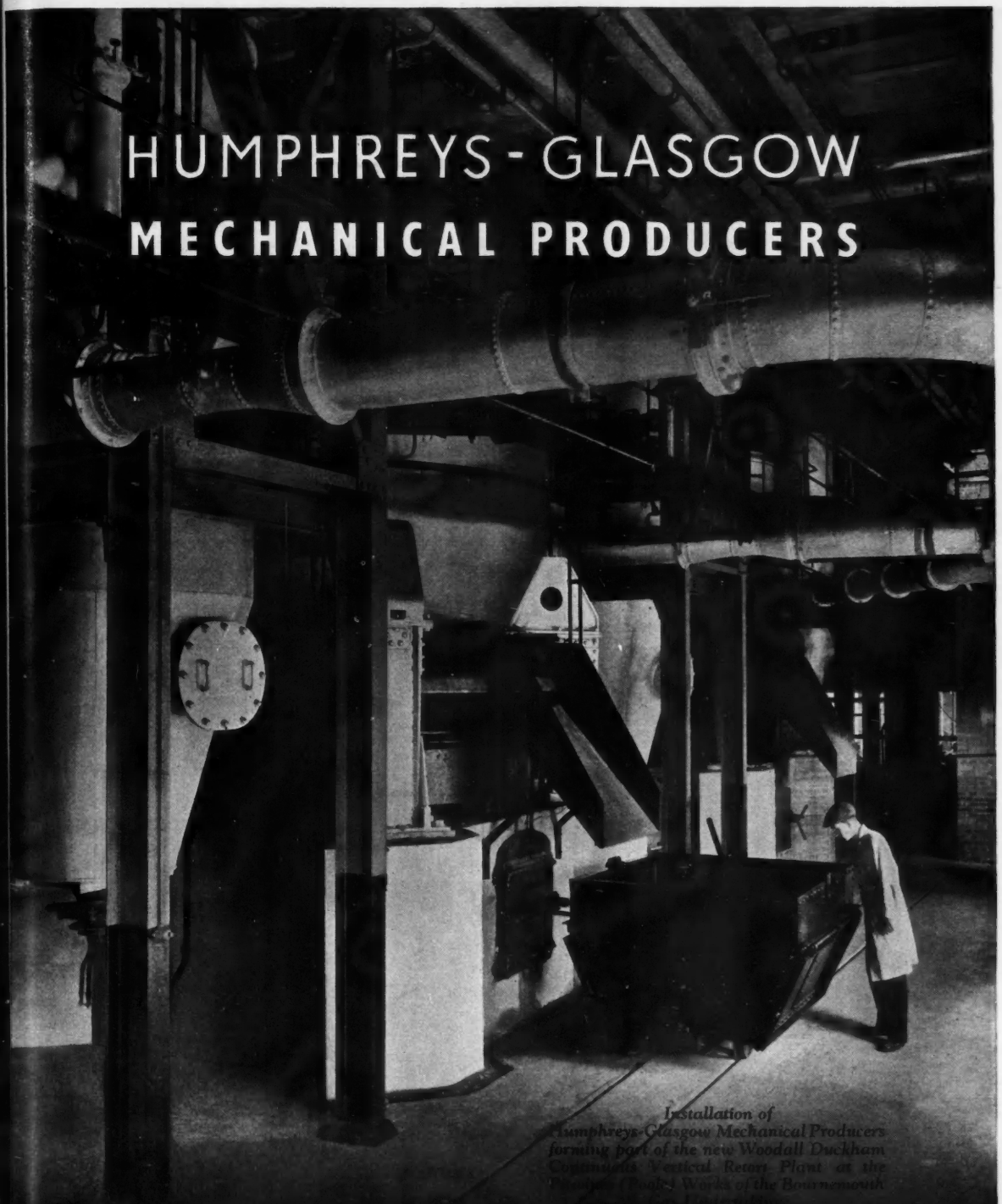

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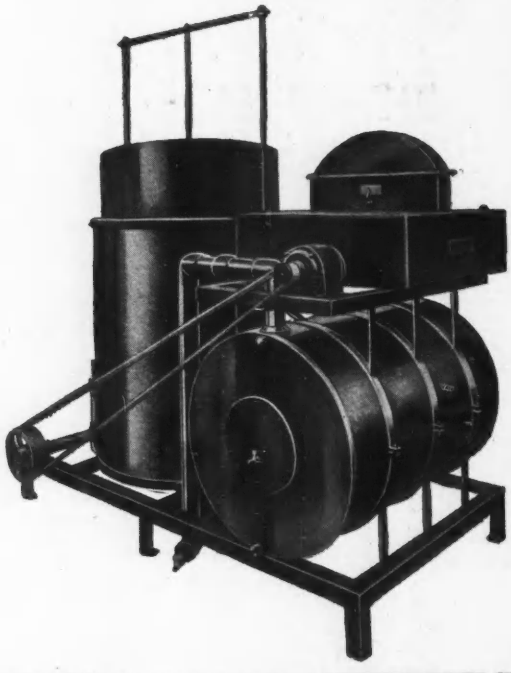

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# GAS JOURNAL

VOL. 264. No. 4561 102ND YEAR NOVEMBER 1, 1950

## THE GAS TURBINE

THE position of the gas turbine in Great Britain was outlined in the very closely written paper contributed by Dr. D. M. Smith, of the Metropolitan-Vickers Company, a master in this field, to the Fourth World Power Conference. There were no diagrams or illustrations. Some day we should like to see a fully illustrated paper from his pen. The position at September 30, 1949, was that while there are no land power gas turbines yet in service in this country several manufacturers have built and run in their own works turbines ranging from 375 to 2,000 kW capacity. On the other hand three installations are on order for electricity generation in central stations; two rated at 15,000 kW are for the British Electricity Authority, and one for the North of Scotland Hydro-Electric Board of 12,500 kW. All these are to burn liquid fuel. In addition there is the waste heat recovery plant now under construction for the Coventry gas undertaking, a model of which was shown at the exhibition at the Birmingham University in connection with the annual meeting there of the British Association.

The thermal efficiency of these installations will be somewhat lower than in the best coal-fired steam boiler turbine plants. Higher efficiencies can only be obtained at the cost of more elaborate and expensive combinations. Efficiencies of 14 to 18% are claimed for uncompounded plant without regeneration, 20 to 25% with regeneration, and 27 to 32% for compounded plant with regenerator. The gas turbine is likely to be an attractive proposition in the power station only for peak load requirements, for while the more elaborate arrangements in the larger sizes promise a thermal efficiency comparable with that of the new steam stations, the oil fuel consumed for the turbines will be higher in cost per heat unit than coal. The decision may turn on capital cost. The diesel engine will be a formidable competitor in the smaller power range. Another attractive feature, especially where renewals of old stations are required, is the economy in cooling water. Open-cycle gas turbine plant can be installed requiring no cooling water though with an efficiency of 23%, while the addition of a single intercooler raises the efficiency to 28% at the expense of cooling water one-third that of the steam plant.

Thermal efficiency in the gas turbine is limited by the temperature-resisting properties of the metal parts with which the products of combustion or heated air come into contact. In the direction of cooling devices to circumvent this difficulty and in the development of more elaborate cycles with multi-stage intercooling and reheating much work is going on. The only adequate way of testing any major advance is to build and run plant over pretty long periods, and progress will only be obtained by considerable expenditure of time and money on experimental plants.

Dr. Smith is of the opinion that there will be no great scope for gas turbines in Britain until they can use coal with an overall economy not inferior to that of competitive plant. Work on more than one coal-burning gas turbine is expected to be started in the near future. The obvious solution of the problem is to burn coal in an external combustion chamber, transferring the heat to the working medium and exhausting the products of combustion to atmosphere, replacing, in short, the boiler by a heat interchanger. It seems, however, that there would be no saving either in size or cost, and the thermal efficiency would be lower than that of the steam plant. The next solution is to use pulverised coal in the same way as oil, but this involves problems of corrosion, erosion, and deposits on the turbine blades and other parts. There are other variants on these.

Gas engineers will be more interested in the proposals to gasify the coal and burn the gas internally in the

turbine combustion chamber. Dr. Smith appears to turn down by-product recovery plant on the grounds that it would be elaborate and lower in thermal efficiency than without by-product recovery. And he looks to some form of producer operating under pressure, some of which have been in service on brown coal for some years in Germany. The gas turbine with pressure producer appears to offer a promising field for the utilisation of low-grade coals in gas turbines.

Another interesting controversy is that between the open and closed cycles. It is noted by Dr. Roxbee Cox, the Reporter in this Section, that with the notable exception of the Escher Wyss Company, in Switzerland, and the John Brown Company, in Scotland, there do not seem to be any serious exponents of the closed cycle system. But he points to the obvious advantage of the closed cycle in that it has no problems of blade fouling and corrosion due to combustion products (except, of course, on the heat interchanger which it shares with the open cycle). He suggests that before acquiescing in the current trend we might be wise to take stock. It may here be noted that the Coventry waste heat installation, for which the John Brown Company is supplying the turbine, is designed on the closed cycle system.

## GAS TRANSMISSION

THE story of the long distance transmission and storage of natural gas in America is a fascinating one. It was told in a racy and informative manner by George H. Smith (U.S.A.) to the Fourth World Power Conference. Natural gas now makes up 13.3% of the natural basis fuel supply in the States, against 50% in all forms of coal and 33% in liquid form. Its use 'as a producer of large and desirable revenues is an industry of comparatively recent times,' while its transmission over really large distances is still more recent, say, since 1926. 'Time was' (we cannot improve on the author's story-telling) 'when it was merely the force which made oil come to the top of the well without effort or expense. After that it was a nuisance; its disposal was a problem. Billions of cubic feet were wasted into the atmosphere or burned in flares.' Now, of 6 mill. mill. produced 2.9 mill. mill. are sold to public gas supply undertakings, while 2.27 billions ($10^{12}$ in our notation) are sold direct or used in the field.

Natural gas pipelines in the U.S. today exceed in mileage the mainline railroads. We have already learned that in the 'thirties three long distance lines were built from the Panhandle oilfield of northern Texas and the Hugolon field of south-western Kansas to Minneapolis, Chicago and Detroit in lengths of 800 to 1,200 miles. During the war a pipeline was laid from southern Texas to West Virginia, a distance of 1,200 miles, while the famous 'Big Inch,' mostly 24 in. in diameter, was run from Long View in eastern Texas to New York, a distance of 1,350 miles, and 'Little Big Inch,' 20 in. in diameter, comes from somewhat farther south, a distance of nearly 1,500 miles to the same region. Diameters have gone up since then to 26 and 30 in., while 32 in. is in the design stage.

And there are some considerable problems in the design and construction of pipelines of these dimensions. The pipes are constructed of welded steel plate and they operate at pressures up to 800 lb/sq in. Thermal expansion presents one problem. It was first solved by the use of a slip-type coupling every second, and later every fourth or fifth joint. But this was soon superseded by a solid welded expansion joint on the bellows or corrugated principle, which itself allowed for some change of direction without bending. For bending was another formidable problem, first solved by the construction of 'bends' in the factory, later by the 'wrinkle' bend, wherein wrinkles are pressed into the pipe making possible a change of direction of about 2° per wrinkle. Thus with a suitable number of wrinkes, spaced 3 ft. apart in the 26 in. pipe, a convenient bend can be contrived. The latest is a smooth bending machine which can bend a pipe to a radius of 38 pipe diameters. Protection against corrosion, which so much exercises our Continental colleagues, is only casually mentioned by the author, listed with such other problems as those of automatic shut-off devices and the design of mainline valves which can be quickly opened and closed, opening to the full diameter of the pipe.

Perhaps the section of this interesting paper which is the most relevant to our problems is that dealing with storage. One can readily imagine what a formidable question this is, on a line 1,500 miles long, with compressors installed every 100 to 150 miles pumping prodigious quantities of gas which issues from its source at practically constant rate—the question, that is, of dealing with hourly, daily and seasonal variations in demand. Underground storage, in depleted oil fields, has been developed to a great extent in the U.S.A. where it provides more storage at less cost than can be provided by any other method. Over 440 billion (*i.e.*, $10^{12}$) cu.ft. of capacity is now in use. But this method is not likely to interest us—yet.

The pipe battery, on the other hand, might provide a substitute for the conventional gasholder. Its main advantage, to our mind, is that, manufactured by production line methods in highly mechanised plant, it can be produced at a lower cost per ton of steel involved than the ordinary gasholder; also, because it is used for storage under pressure, as high as 1,600 lb/sq. in., the weight of steel required per unit capacity is less than that in any other type even of pressure holder. This advantage is further increased by the use of high-tension steel. In the State of Illinois there is a pipe storage plant of 40 mill. cu.ft. capacity (free gas) in 24 in. molybdenum seamless steel pipe, ½ in. thick, capable of withstanding pressures up to 2,240 lb/sq. in.

This solution of the storage problem is, of course, that of the pressure holder, which in this country has so far been limited to small capacities. Does the pipe battery represent a development which might lead to the extension of the pressure holder to major storage problems? Against it is the cost of compression and release equipment. In Illinois, it is stated, the cost of the pipe battery holder together with this equipment is less under most operating conditions than that of the conventional gasholder.

# TOWN GAS IN A DENTAL WORKSHOP*

By WILLIAM KIRK,
Engineer and Manager, Motherwell and Wishaw District, Scottish Gas Board.

SINCE 1939 the use of gas for industrial purposes has increased by leaps and bounds and many technical papers on numerous processes have been read and published on this particular subject. The commercial market, however, has not been publicised to the same extent.

One does not normally associate town gas with a dental establishment; nevertheless, there are many uses for gas in such a place with a few of which I propose to deal in the course of this paper. Among the first enquiries received following publication of a special rate for central heating purposes was one from a prominent dentist in Motherwell. This was followed up in the usual way and to a satisfactory conclusion in that a conversion set was ultimately and successfully installed. This set being one of the first installations, I was more than anxious that it should give every satisfaction. My interest in the various processes described hereafter are, therefore, directly attributable to this enquiry.

## Central Heating

The conversion of solid fuel-fired boilers to gaseous firing is now commonplace, and there are no special features in the set which was fitted which would call for special mention.

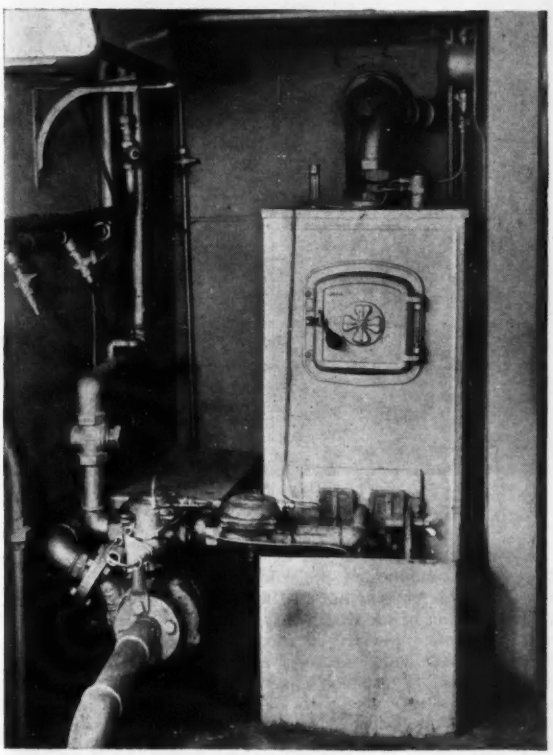

*Fig. 1.—Showing boiler with clock controller in top right-hand corner and part of water circulating pump in bottom left-hand corner.*

When the set was put to work, however, trouble with the pilot jet was experienced. The boiler is fitted in a recess with the main door from the workshop to the consulting rooms on the one side and the main exit door from the workshop on the other. The consulting room door was continuously being opened and closed and the air currents created diverted the pilot jet from the end of the thermocouple. The same trouble was caused by the exit door, but not to the same extent. The pilot light was enlarged and proved ineffective, but when a metal screen was fitted the trouble was completely eliminated and the apparatus functioned perfectly. The average yearly consumption is in the region of 430,000 cu.ft. and this set has been one of my best advertisements.

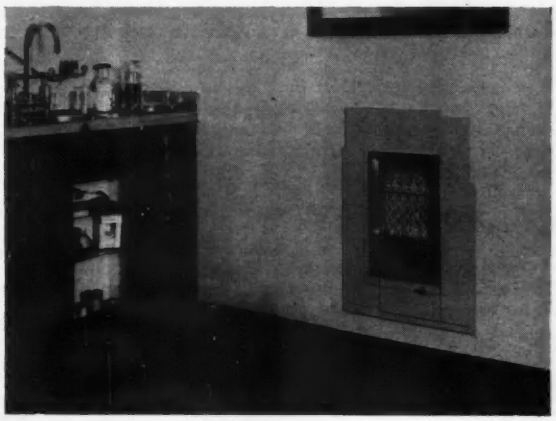

*Fig. 2.—'Panamain' Panel Fire.*

When selling central heating equipment it is normally pointed out to the consumer that the installation should be for supplying background heat and that some other form of heating—e.g., gas fire or coke fire—should be used when a room is to be occupied of an evening. A temperature of 40° F maintained in the house during the coldest months will ensure that the furniture is kept in good condition, that the hall of the house shall not be an icebox where a sick person could, in addition, contract influenza going to and from the bathroom. The following photograph shows a gas fire for occasional heating fitted in No. 3 surgery and it will be admitted, I am sure, that the setting is quite attractive.

## The Making of Dentures

A brief description, at this stage, of how dentures are made may be helpful in understanding the various processes which are described later in greater detail.

The patient's teeth having been extracted an impression of the mouth is obtained by placing therein a metal tray holding a composition such as Denticol, Zelex, etc. This impression is filled with plaster of paris giving a model from which a wax block, termed bite block, is made. On the next occasion of the patient's visit, the wax bite block is softened slightly and inserted in the patient's mouth in order that the true relationship between the upper or maxilla and lower or mandible jaw is obtained. The next step is to mount the wax blocks and plaster of paris models on an articulator—*i.e.*, a metal clamp arrangement giving a movement similar to opening and closing of one's mouth, when the teeth are then set in the wax blocks. The patient is again called to the surgery and the wax block with the teeth affixed is inserted in his or her mouth so that the bite can be properly checked and the teeth correctly aligned.

The model and wax block with teeth set in position are

* Paper to the North British Association of Gas Managers, Oban, September 21, 1950.

invested (embedded) in the shallow portion of a flask (metal container) using plaster of paris as the investment or embedding material, the model being held in the plaster while the wax, with teeth in position, is left above the level of the plaster and, when set, the surface is lubricated with soap or vaseline or such similar material which facilitates the opening of the flask after treatment in the hot closet. The deep part of the flask is filled with plaster when both parts are brought together and placed in the hot closet. After a time the flask is opened and the wax 'boiled out'—*i.e.*, completely removed by means of boiling water (see Fig. 4), leaving the teeth embedded in one portion of the flask and the original model in the other. The two halves of the flask are returned to the hot closet and left there in order that the investment may be thoroughly dried out before receiving the resin.

The dough (acrylic resin) having been prepared is packed into the mould to take up the space recently occupied by the wax. The flask is then placed in a spring tension or a screw clamp, the whole being put into the water bath for the processing or curing of the resin.

In concluding this brief note on the manufacture of dentures, I would make mention of cleanliness which must be exercised to the nth degree. Scrupulous cleanliness must be observed at all stages in order to avoid contamination in any form whatsoever.

## Casting of Metal Plates

One day when I walked into the workshop I found that the damper near the top of the furnace was half open, and upon closer inspection I noticed an iron bar extending from front to back of the boiler and sitting on the bar was a container. It was obvious that a process of some description was being carried out and enquiries revealed that a metal plate was being cast.

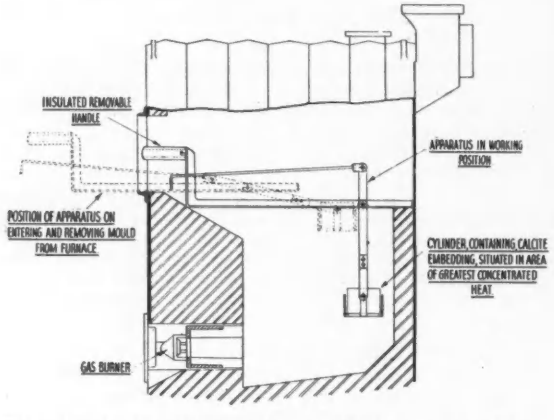
INSULATED REMOVABLE HANDLE
APPARATUS IN WORKING POSITION
POSITION OF APPARATUS ON ENTERING AND REMOVING MOULD FROM FURNACE
CYLINDER CONTAINING CALCITE EMBEDDING, SITUATED IN AREA OF GREATEST CONCENTRATED HEAT
GAS BURNER

*Fig. 3.—Section of boiler with specially fabricated tool for casting of metal plates.*

A wax pattern of a plate is taken and is invested in a cylinder roughly 3 in. diameter. When this investment has hardened sufficiently, the cylinder is placed in the gas furnace and brought to a high temperature and the wax is incinerated. The cylinder is then transferred quickly to the centrifugal casting apparatus wherein there is a crucible containing molten gold. This apparatus is set in motion and the gold is thrown into the cavity which originally contained the wax pattern and allowed to cool, after which the investment is broken up to release the plate.

I do not know whether this example would make a good selling point in this particular line or whether it is another illustration of the Scots hatred for waste, by utilising to some extent the waste gases in the furnace. Nevertheless, to facilitate the work a special tool was designed for the job in hand.

## Recovery of Wax

The wax adhering to the mould is recovered not for its actual money value but because the moulds must be absolutely free of wax and also to prevent drains from becoming choked. To accomplish this a kettle of water, sitting on an iron plate heated by a gas ring, was always kept at boiling point ready for use. This was a wasteful and expensive method of utilising gas and a boiling water heater was obviously required.

An Ascot RS 52/1 was fitted and there was no doubt about its capacity and efficiency for the job, but, to make the task lighter for the assistant, a special tool for holding the flask was devised. The flask containing the wax over which the boiling water was poured was not easily handled, and a tool into which the flask was slipped was made. So long as the tool was held in a downward direction the flask could be turned any way without falling out. This enabled the assistant to hold the flask near the spout of the water heater without any danger of being scalded with boiling water.

The average weekly consumption works out at 300 cu.ft.

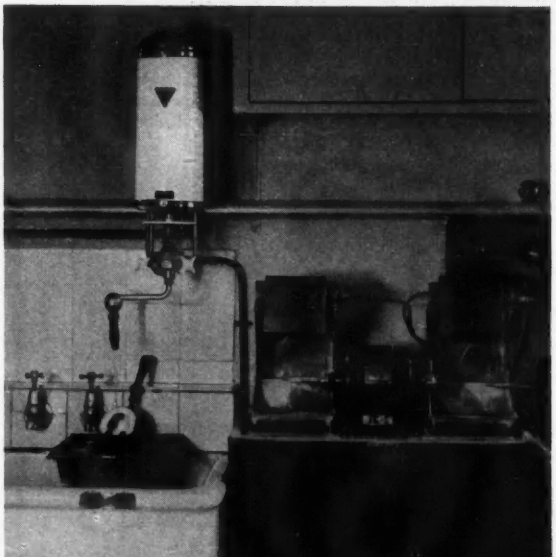

*Fig. 4.—Ascot Boiling Water Model dewaxing an impression.*

Shown on the right of the water heater, Fig. 4, is an electrical dust extractor and polishing machine which is interesting. Through the rear hood of this unit the fine dust created in the polishing of the dentures is exhausted to the atmosphere outside. Pumice powder is used when polishing teeth and silicosis of the lungs is always a danger unless the operator wears a mask. This machine (and to the best of my knowledge there is only one other in Britain) obviates the use of masks and also prevents the air in the workshop from becoming contaminated with the very fine particles of powder.

## Dewaxing Dentures

Mention has already been made of an iron plate heated by a gas ring upon which sat a kettle. This plate was also used to dry investing moulds by placing them round the kettle; it will be obvious that uniform heating of the moulds could not take place since the bottom half received all the heat.

Only a limited number of flasks could be accommodated on

the iron plate; consequently delays were unavoidable and output of dentures was slowed up. After some thought on the matter, a hot closet of the cooker type was fitted with two iron shelves and tried out. The heat input was found to be on the low side and this was made good by the addition of two neat flame burners. The apparatus was finished in cream enamel and when fitted to the wall gave a pleasing appearance.

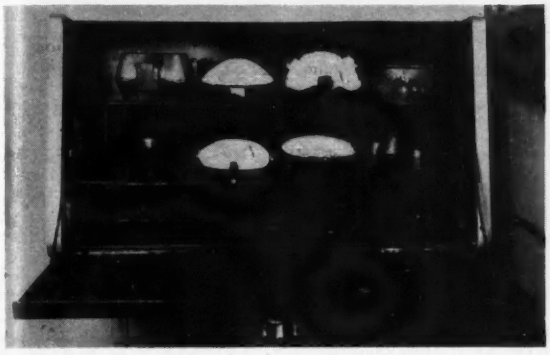

*Fig. 5.—Drying out moulds. Note teeth in position after dewaxing.*

The denture, made of wax, is invested in plaster of paris contained in a flask and put into the hot closet where it is held at an even temperature just high enough to soften the wax without having it molten. When the flask is opened the plaster mould is in one half and the wax and teeth in the other half. The wax is 'boiled out,' using the Ascot water heater, following which the flask is returned to the hot closet to dry out the investment in preparation for packing with acrylic resin.

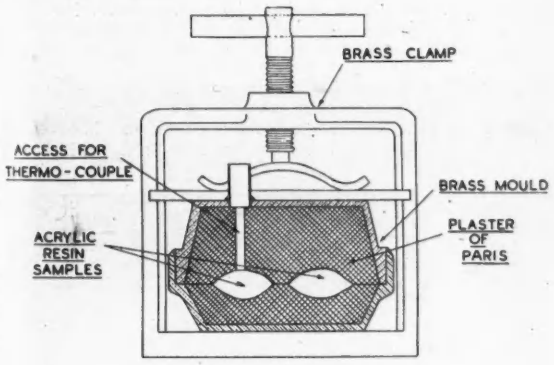


*Fig. 6.*

## Curing of Acrylic Resin

There is no doubt that it pays dividends to keep in touch with the consumer. In this workshop, sitting on the floor, was an old stockpot but my interest therein was not aroused until one day when I noticed a thermometer in the vessel which was being heated by a gas ring. I enquired as to what was cooking and thus came about my interest in the curing of acrylic resin.

The basis of all acrylic resin base materials and dentures is methyl methacrylate, which is a thermoplastic synthetic resin. It is coloured by the addition of inert pigments and may or may not contain small quantities of plasticiser. The liquid or monomer and powder or polymer are the same material. The monomer is methyl methacrylate in molecular form and the polymer is made up of minute collections of polymerised molecules.

It has been mentioned that plasticisers may be present and these are chemicals of an oily nature which increases the flowing power of the dough—*i.e.*, mixture of the monomer and polymer—by acting as a lubricant to the molecules. Their presence usually accelerates the formation of a workable dough and it is probable that their use weakens the end product, thereby increasing its liability to fracture.

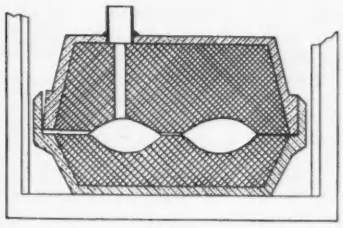

*Fig. 7.*

The curing of the resin proceeds in a number of well defined steps, viz.:—

(1) Mixing of the monomer and polymer.

(2) Investing the mixture in the flask.

(3) The heating of the mixture.

The generally accepted proportions for the mixture is three of polymer or powder to one of monomer or liquid. It has been observed, however, that these proportions when applied to particular resins do not give the result desired, and in some cases an excess of powder was indicated and in others an excess of liquid. Care must be given, therefore, to the proportions in order to achieve consistent results.

The time taken to prepare the mixture or dough is also of some importance since the dough must be of a certain consistency, and this is obtained by allowing the materials in the dough mixer to attain room temperature. The greater the amount of excess liquid the longer is the time in arriving at the packing consistency stage. Also the greater the amount of excess liquid in the mass the greater is the tendency to porosity, which ranks as a bad defect in the denture and must be eliminated. The correct consistency is judged by the behaviour of the mix when it is stirred and handled. In the early stages it has a very stringy consistency and later can be kneaded by hand to a tough dough-like consistency at which stage it is ready for packing into the mould.

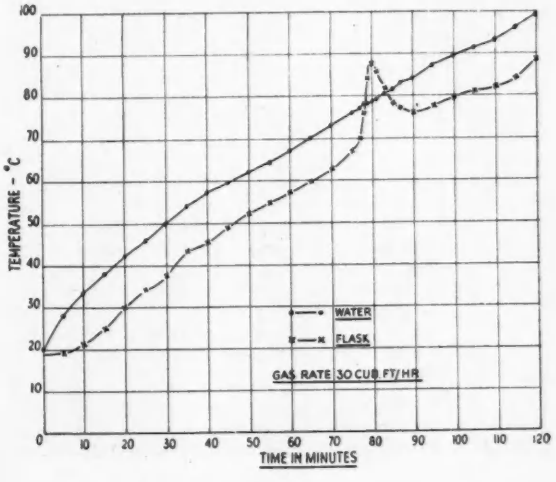


*Fig. 8.*

Experience has shown that different products have different variations in porosity, but, generally, porosity will be reduced to negligible proportions if the polymer is mixed with the monomer to produce satisfactory dough.

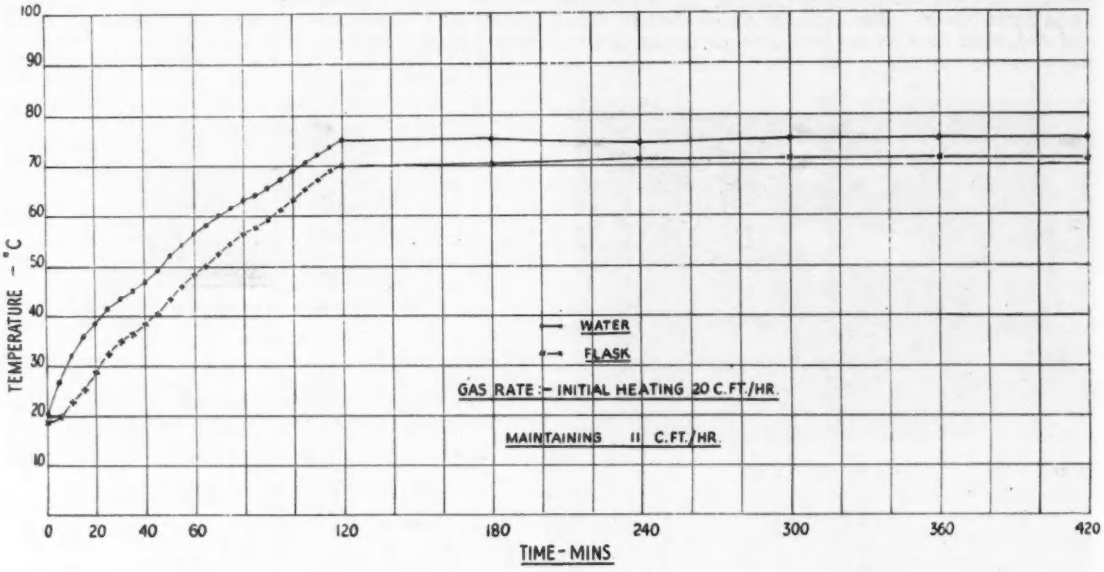


*Fig. 9.*

## Investing the Mixture

The dough, after standing at room temperature for ½-¾ hr., should have reached a suitable consistency for packing into the mould which should also be at room temperature. Should the mould be at a higher temperature than the dough, the dough may become so stiff that the proper packing of the mould is affected. There should be a slight excess of dough when the mould is filled, and pressure should be applied slowly until both halves of the flask have come together (see Fig. 6 and 7). After complete closure the flask should be opened and the excess material pared away and the pressure re-applied. This operation should be carried out at least twice before finally closing the flask. Both halves of the flask must meet accurately and it will readily be apparent that an excess will not permit of this and will give rise to a faulty denture, and, if there is too little dough, porosity will be present in the finished article. When the flask has been packed it can be allowed to stand for an hour before the curing operation begins. This allows the resin mass to take up all the detail of the mould and also relieves the internal stresses in the early stages after closure. The plastic mass is slow in its movement; consequently, if curing is proceeded with immediately upon closure of the flask, internal stresses are set up which can be obviated by a short interval of time before curing.

## Heating of the Mixture

The most suitable temperature for curing has been determined as 75° C (±2°), but there are some resins which can

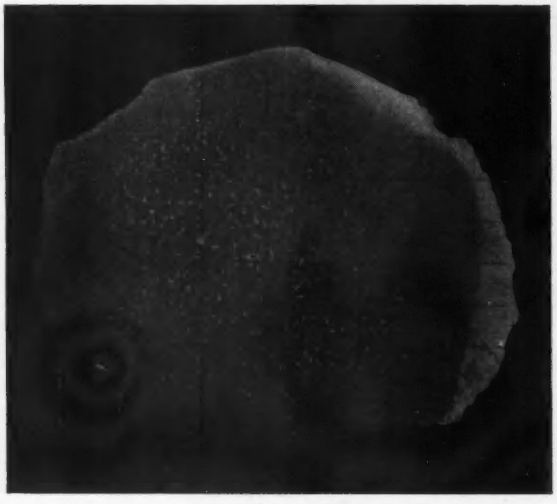

*Fig. 10.—Heating to 75° C in 77 minutes showing porosity.*

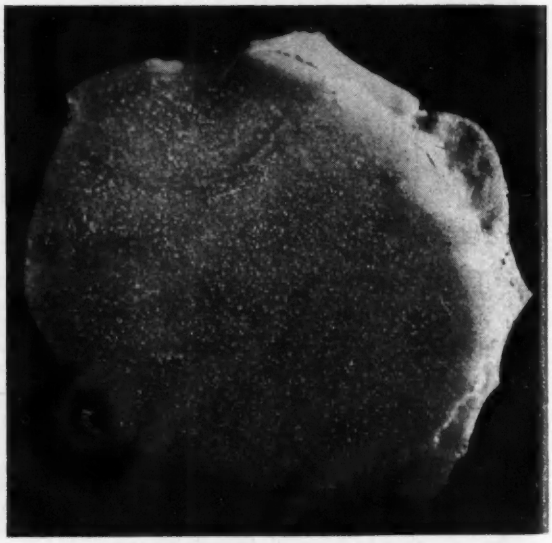

*Fig. 11.—Heated to 75° in 2 hr. and maintained for 5 hr. but dough not properly packed.*

*Fig. 12.—Heating to 75° C in 2 hr. and maintained for 5 hr.*

be treated at 82° C without encountering any difficulties. In curing, time again plays an important part and there are divergent schools of thought in this connection. Some authorities plunge the flask into a water bath at 75° C (±2°) and hold it at that temperature for not less than 4 hr., others place the flask in water at room temperature and raise to 75° C (±2°) in two hours and hold it at this temperature for 5 hr., and others use a two-stage heating system—viz., 90 min. at 75° C (±2°) and then raising to 100° C for 60 min. It would appear, therefore, that the method employed is at the option of the operator and the equipment which is at hand. Generally speaking, the preference is for the long period of low heating since no real harm can be done. In the short period of time an undercured result is obtained if the temperature is insufficient, and a similar result occurs when too short a time is allowed in the low temperature curing process.

*Fig. 13.*

*Denture on left cured in stock pot. The lingual and buccal surfaces appeared perfect but when cut through internal porosity was apparent. Denture on right cured in water bath. Porosity absent.*

A scientific background based upon the critical polymerisation temperature tends to support the adherents of the low temperature long period process. It has been determined that methyl methacrylate polymerises readily at a temperature of 70°-75° C. At this temperature the exothermic heat of polymerisation is liberated. If the temperature of the water bath is in excess of 75° C the heat is liberated rapidly to elevate the temperature sufficiently to cause porosity. Again, such a rapid rise in temperature may set up internal stresses and warpage in the finished product. High temperatures are conducive to shrinkage and other irregularities; hence the reason for the majority of practitioners employing the low temperature long period process of curing.

The average gas consumption worked out at 250 cu.ft./week or just short of 6 cu.ft./cured denture.

My researches into the treatment of acrylic resin has brought to my knowledge that there are several methods of processing these resins apart from a water bath, but, while some are inferior, and some are equal, none appears to be superior to the water bath. I do not propose to give a detailed account of these methods, all of which are designed to ensure constant temperature conditions, but a brief mention may be of interest.

*Fig. 14.—Stockpot.*

(1) Water vapour method—results equal but not superior to water bath.

(2) Dry heat developed by two electrically heated platens applied to the flask under compression—accurate temperature control is difficult; results not superior to water bath.

*Fig. 15.—First experimental boiler.*

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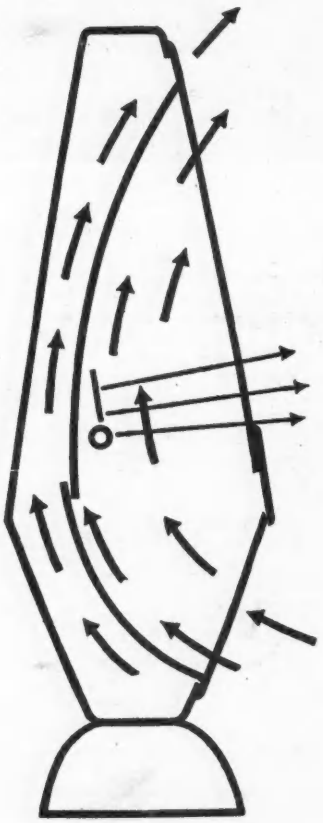

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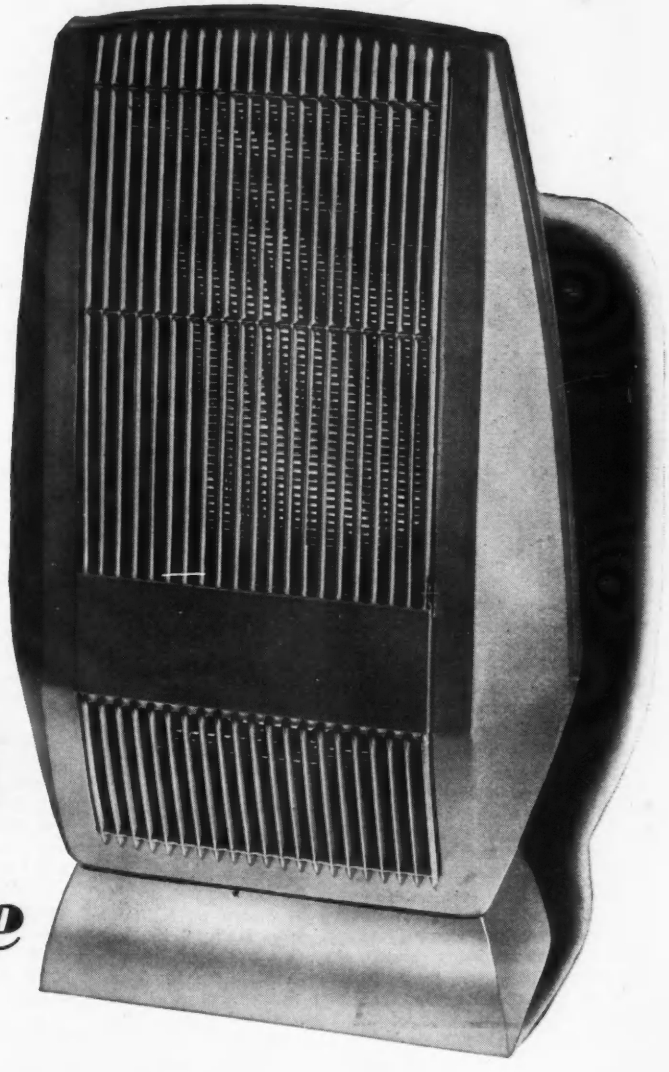

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(3) Dry air oven—as in (2) above.

(4) Infra red light bulbs—accurate temperature control. Superiority over water bath claimed.

(5) Induction or di-electric heating—efforts now being made to apply this method.

It will be noted that temperature control is the keynote and all of the processes aim at accurate control during the

*Fig. 16.—Second experimental boiler.*

curing stage as this appears to be the most important item in the process. The uniformity in heating, the simplicity in operation, and the flexibility in heat input, coupled with a reliable thermostatic control, give the gas heated water bath, in my opinion, an advantage over other methods of heating.

That gas apparatus for this job would be available I had no doubt, but whether my enquiries were wrongly or insufficiently directed the only information I could get concerned electrically-operated appliances. In these circumstances there was just one thing to do—make a gas-operated vessel for the job in question. A search of the store revealed an old square type washboiler complete with run-off cock but nothing else. It was an easy matter to make a suitable stand and fix a clock controller thermostat, governor, and thermometer. This worked fairly well, but unfortunately the bottom was so thin that it did not stand up to the weight placed on it. Each complete flask and clamp weighs approximately 9 lb., and with 10-12 flasks being treated plus the weight of water a total of approximately 1 cwt. was contained in the apparatus. It was not surprising, therefore, that the bottom gave way. Another boiler, this time of the conventional circular type, was obtained and the controls were changed over and in addition a circular type temperature indicator was also fitted, which permitted the operator to see the actual temperature of the water in the boiler. Meanwhile a design of an apparatus for this particular heat treating job was under way. Difficulties were cropping up all along the line but a makeshift having many advantages turned up in the shape of a Main deep fat fryer.

A new thermostat assembly had to be obtained and the thermostat re-calibrated to suit conditions, and a special tray to hold the flasks required to be fabricated before a trial could be given. This machine is now working and is giving excellent results. Meanwhile, the pursuit of an apparatus for the particular job in hand still goes on.

The photographs, Figs. 14, 15, 16, and 17, illustrate the evolution of the apparatus.

It will be observed from the photographs that a simple cut-off is fixed on the *outlet* of the controller. This ensures that no gas will pass should the time controller be 'on' when no work is being processed—e.g., a Sunday. I do not require to point out the merits of a clock controller. Suffice to say that with this arrangement the practitioner can load the boiler before going to bed, knowing full well that the curing will be properly done while he sleeps. In a busy practice this method allows two charges per day, and in these times when the volume of work is overwhelming this is of undoubted advantage.

Simplicity in control is exemplified by the handling of the fuel being reduced to the mere lifting of the plunger on the cut-off device, and, also, the automatic time and temperature controllers are as foolproof as can be had. Cleanliness is of

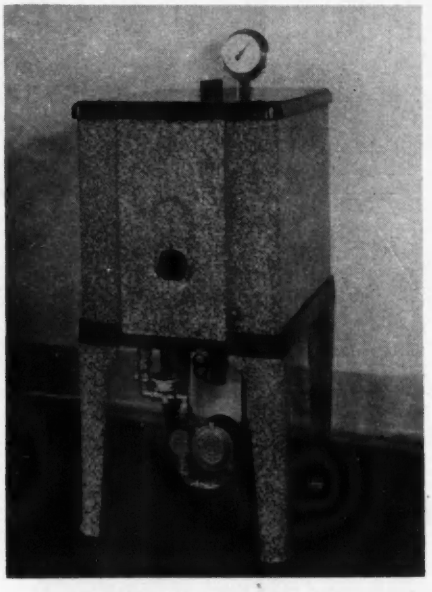

*Fig. 17.—All enamelled boiler.*

paramount importance, as I have already indicated, and no qualms need be felt with the gaseous fuel we supply.

When a broken set of dentures has to be repaired much trouble is caused through warpage, and this subject is being thoroughly investigated at the moment. How the difficulties will be surmounted I do not know, but it may well be that a new form of resin may be the solution. It may also be that a new heat treatment technique will require to be adopted; and this brings me to the point of flexibility. As far as I have been able to determine, electrically-operated apparatus has three heats—namely, low, medium, and high. With gas apparatus any degree of heat change can be obtained without difficulty.

## Working Results

Observed tests over a period of six weeks produced the following results:—

| | |
|---|---|
| Curing processes ... ... ... ... | 1,500 cu.ft. |
| Dewaxing ... ... ... ... | 1,800 cu.ft. |
| Investing hot closet ... ... ... | 600 cu.ft. |
| Bunsen burners, gas fires, etc. ... ... | 900 cu.ft. |
| Total gas consumption ... ... ... | 4,800 cu.ft. |
| Dentures made ... ... ... ... | 252 |
| Gas consumption per denture ... ... | 19 cu.ft. |
| Cost per denture with gas at 12.3d./therm ... ... ... ... ... | 0.99d. |

I regret that I have been unable to obtain a cost per denture when processed by electricity.

Since dentists are not allowed to advertise there is a difficulty in obtaining information concerning practising practitioners, but it would appear that the number might well be 13,000 or thereabouts. I am of the opinion, therefore, that speculation in this direction should not be undertaken since it might be most misleading. The same applies to the number of dentures made, and again I am sorry that I cannot expand my calculations to show the effect on the industry. When the results and analyses of the working of the Health Scheme are published, there may be more accurate information available upon which calculations can be based.

## Service After Sales

There is increasing evidence each day that our principal competitor is making gigantic efforts to increase the sales of electricity, and there should be no complacency because of cuts in supply in recent times. Generating plants are being expanded and the powers that be are not doing this without hope of the plant being fully employed. Electrical competition will become keener, more concentrated, and more competitive than ever before. Therefore, we must be prepared to the full to meet this onslaught and one way of so doing is 'service after sales.' We must make certain that our commodity is beyond reproach, in that the calorific value is kept fairly constant and that adequate pressure is maintained; that the supply is free from impurities at all times; that block system of charging or two-part tariff or have what you may, must be designed to encourage more sales and new business; that all appliances are reliable and economical; and that our service both before and after sales is as near perfection as can be got.

It must be a prerequisite of any policy in this direction that the staff handling this service must know thoroughly their various jobs. In the past we have been dependent upon fitters drawn from plumbing establishments for servicing appliances. Now that there is a proper scheme in being for training and certification of gasfitters, the standard of efficiency in servicing should show, in due course, a marked improvement. I would like, however, to suggest that there is still a further step to be taken, and that is the creation of specialist gasfitters. Such employees would undergo a further period of training in specific directions—e.g., on automatic controlling equipment or on governors and the like. This would give better service to the consumer and at the same time enhance the reputation of the local undertaking and the industry in general.

This endeavour to show how gas can be applied successfully to the several processes involved in the manufacture of dentures should be construed from the technical utilisation aspect rather than from a load building angle, since there is insufficient information at my command successfully to develop this theme.

The loads to be obtained are apparently not as large as normal commercial loads, but the opportunity of building up goodwill is there and ought not to be missed. In the years before us, all the goodwill we can get will be required if we are successfully to combat the strong opposition, the vanguard of which is already in the field. No load, therefore, however small should be wantonly disregarded.

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# SAFETY IN RELATION TO STREET LIGHTING*

By A. J. HARRIS, B.Sc.,

Traffic and Safety Division, Road Research Laboratory.

THE Road Research Laboratory of the Department of Scientific and Industrial Research was originally set up for research into materials and methods of road construction. It was not concerned with the safety of the roads, nor with other aspects of their function as traffic arteries. It had begun, however, even before the last war, to investigate the slipperiness of road surfaces, and so to take the first steps towards the new field of road safety. Further steps were being contemplated, but the war brought progress in that direction to a halt as well as diverting most of the energies of the laboratory to military problems. It was not until 1946, when peacetime work was being resumed, that the terms of reference to the laboratory were enlarged to include both road safety and traffic flow, and that the organisation of the laboratory began to assume its present form.

The research staff of the laboratory is now grouped into two divisions and the divisions are divided into sections. The original work of the laboratory is carried on by the Materials and Construction Division, with sections devoted to soils, concrete, bituminous materials and special problems. The Traffic and Safety Division deals with the new field and has sections on traffic, surface characteristics, vehicles, road users, lighting, and statistics.

## Work of the Lighting Section

The lighting section deals with vehicle lighting as well as street lighting, and up to the present has devoted rather more of its energies to the former. It has studied the problem of seeing with vehicle lighting under conditions of glare, testing different beam distributions, and studying the effects of varying the candlepower and the speed, with the aim of finding the type of lamp which shall give the best seeing and a minimum of discomfort. Some work has also been done on the design of foglamps. In the field of street lighting there are the long-term problems of relating the accident situation to the quality of the lighting, and of finding a satisfactory measure of the visibility in a lighted street. Work is being done, too, on the reflection properties of road surfaces. It is felt that the laboratory is especially well placed for making a useful contribution here, since it is concerned with all other features of the road surface, particularly slipperiness. The demand of the road engineer for a non-skid surface will have to be reconciled with the lighting engineers' demand for a surface which shall not waste most of the light which his lamps throw upon it. Also included in the research programme are the lighting of roundabouts, junctions, dual carriageways, signs and obstructions, but it has not been possible to commence work on these.

## Revealing Power in Lighted Streets

The question of finding a satisfactory way of assessing visibility in lighted streets is included, as already mentioned, in the long-term programme of the lighting section. Revealing power is the capacity of the installation to reveal any objects which may be in the street. Very crudely the numerical value given to revealing power is the chance, expressed as a percentage, of seeing an arbitrarily chosen pedestrian against the background of the road surface. This is a quantity which, though depending on the properties of the average

*From a paper on 'Some Problems in Road Safety connected with the Lighting of Streets,' presented at the annual meeting of the Association of Public Lighting Engineers, Bournemouth, September 21, 1950.

human eye and the motorist's reaction to objects in the road, is obtained for any particular installation from measurements which are purely physical: the brightness of the road surface and the illumination of vertical surfaces in the street, *i.e.*, the illumination which determines the brightness of the pedestrians. Thus the revealing power is not a single number applicable to the road as a whole but a quantity which varies from point to point unless the road surface happens to be of uniform brightness. The illumination of vertical surfaces, the other quantity on which the revealing power depends, varies considerably along the street, being high just beyond a lamp and low just on the observer's side of it. In consequence of having to take into account this considerable variation it did not appear possible to exhibit revealing power as a function of one or two simple variables. Each installation had to be treated separately. It was noticed, however, at the laboratory that fairly accurate results were obtained if one merely averaged the illumination of vertical surfaces and found the revealing power as if the illumination was uniform and of this value. This was found to be true for installations of different types provided the variation in illumination was not too large, and it appeared that for Group A lighting, where the span does not exceed six times the mounting height, the error would not exceed a few per cent.

Pedestrians who are visible against the background of a road surface may appear darker or lighter than that background. Usually they are darker, that is, they are seen in silhouette; the lighter ones are said to be seen in reversed silhouette.

In interpreting numerical values and considering their bearing on road safety it must be remembered that the basic data from which revealing powers are calculated were obtained with stationary objects and that it is assumed that the object is seen against the background of the road surface.

## Increasing the Visibility of Pedestrian Crossings

The laboratory has devoted a good deal of attention to devising a type of surface-marking for pedestrian crossings which should be recognisable at a greater distance than the studs or beacons which are now an essential part of any pedestrian crossing. A surface-marking might catch the eye of a driver more easily than a beacon placed at the side of the road; it might also have a greater attraction for pedestrians. Many different kinds of marking were already in existence and these were first examined. Many made use of white or coloured stripes, laid across the road or diagonally; others used black and white 1 ft. squares forming a chequerboard pattern. Metal plates were also used, in full or broken lines across the road. Observers tried first to compare the different types of marking by determining the distances at which the crossings could be recognised from a position on the edge of the pavement, but it soon became obvious that variations in other things besides the type of marking made it impossible to assess the merits of the different crossings in this way. This was particularly obviously when observations were made at night; the visibility of the crossing depended enormously on the street lighting and on the position of the crossing in relation to the lamps.

## Finding the Best Pattern

It was decided therefore to examine a number of different patterns on a model road built to a scale of 1 to 24. Observations were made both in daylight and in the illumination provided by the model street lamps, the power of which could be controlled. Since the aim was to produce a marking visible from as great a distance as possible, observations were made from a position corresponding to that of a driver 300 ft from the crossing and with his eyes 5 ft. above the road surface. A number of observers took part in judging the different markings and there was general agreement that the most conspicuous was the type which has become known as the 'Zebra' marking, consisting, on full scale, of alternate black and white longitudinal stripes 2 ft. wide. No advantage was found in the use of colours other than black and white. No marking was really satisfactory in street lighting but the best results were obtained when the marking was as bright as possible, particularly if illuminated by a floodlight above the crossing, the extra light being confined to the area of the crossing itself.

## The Use of Floodlights

On behalf of the laboratory a floodlight was set up in Slough High Street. It was mounted at the side of the crossing at a height of about 20 ft. and illuminated only the area of the crossing. The illumination at the centre of the crossing could be raised from very low values to 10 lumens per sq. ft. From observations of the light necessary to provide certain standards of visibility for persons standing in the street or driving along it, it was concluded that an illumination of about 5 lumens per sq. ft. was enough to make the Slough crossing recognisable from a distance of 400 to 500 ft but that in better lighted streets this would probably be inadequate. There was also a tendency, especially when the crossing was seen from a large distance, for it to appear as a plain bright band across the road, the contrast between the black and white not being at all conspicuous. A number of floodlights were later installed at 'Zebra' crossings.

In the experiment carried out at Slough High Street both the black and the white areas of the crossing were illuminated by the floodlight, *i.e.*, the white could not be made brighter without making the black brighter also. In model experiments it was possible to vary the brightness of the dark areas independently, and it was found that the brightness of these was very important. If the dark areas were darker than the road surface the crossing was much more conspicuous than when they were brighter than the road surface. In one case, for example, making the dark areas darker than the road surface reduced the necessary excess brightness of the white areas from 80% of the road surface brightness to 10%.

The importance of the dark areas of the marking having been demonstrated by the model tests, means were sought to reduce their brightness on the road. Special lanterns illuminating only the white areas of the crossing would have been too elaborate; the method adopted was to reduce the reflection factor of the dark areas mainly by roughening them. This was first done by surface-dressing the areas with a dark crushed stone, and this was found to be extremely effective.

Crossings marked with plastic whites and roughened blacks are effective on well lighted streets where the road surface is fairly uniform in brightness even when the road is wet, provided it is not so wet as to flood the rough areas as well as the smooth. They are not so effective when the street lamps are few in number and low in output particularly when the road is wet. A rough dark area does not show up well if it lies in a dark part of the road surface, while the plastic alongside it does not appear bright when wet because, being shiny, it reflects very little light unless it lies in line with a street lamp.

## Effect of Markings on Road Users

Turning from the crossings themselves to the effect they have had on pedestrians and drivers we have reports of a number of studies carried out by the Road User Section of the laboratory. As measures of road user behaviour two quantities were adopted: A pedestrian behaviour index and a driver stopping index. The pedestrian behaviour index is the percentage of pedestrians crossing the road within 20 yards of a pedestrian crossing who actually use that crossing. The driver stopping index is the percentage of drivers who give way to pedestrians at the crossing. In obtaining the latter figure drivers are not counted if they give way simply because they are following immediately behind another driver who gives way, but, for convenience in counting, all other drivers are included whether there is a pedestrian waiting at the crossing or not.

It was found that the pedestrian behaviour index rose after a crossing was striped. This improvement was maintained for at least two years at one crossing at which observations were continued. Women respected the crossing more than men and children were better than either.

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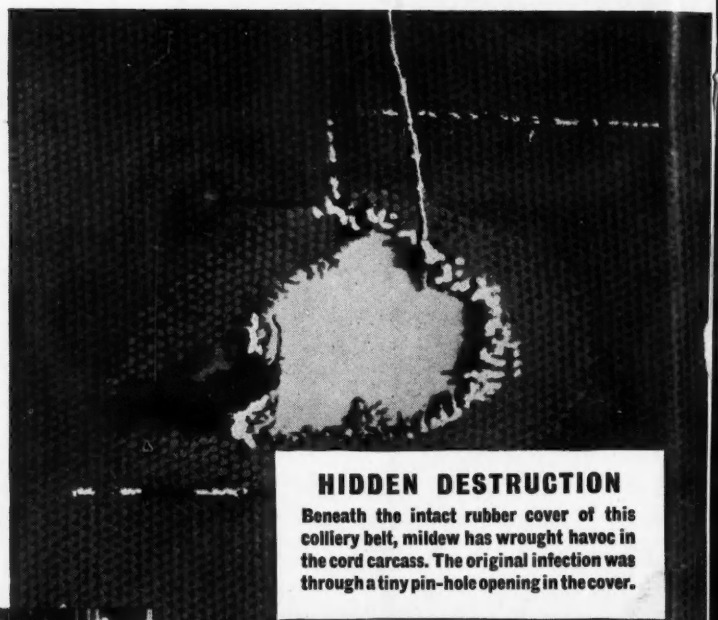
# MILDEW was a menace

## PIONEER WORK BY GOODYEAR RESEARCH TEAM CONQUERS DEADLY BELT-DESTROYING FUNGUS



**HIDDEN DESTRUCTION**
**Beneath the intact rubber cover of this colliery belt, mildew has wrought havoc in the cord carcass. The original infection was through a tiny pin-hole opening in the cover.**

Mildew has always been the arch-enemy of conveyor belting — the cancerous infection that, beneath a belt's perfectly intact rubber cover, can reduce the cord duck to soft pulpy ruin in the course of a few months. The reason for this is that the mildew spore flourishes in the very conditions in which conveyor installations often work—darkness, dampness, lack of ventilation, uniform and moderate temperature, and during prolonged periods of idleness — as in day-shift-only factories and seasonal sugar-beet refineries.

**Isolating the Fungicidal Agent**
**These Chemists, working in one corner of the huge Goodyear Laboratory, succeeded, after months of painstaking effort, in isolating the only agent yet discovered that inhibits the development of the mildew spore.**

Obviously, the conditions in which conveyor belts work are unlikely to change, so the problem could only be solved by the discovery of a mildew inhibiting agent. In the absence of any officially sponsored work, the Goodyear Company undertook the work themselves as part of their normal service to clients. They gave their research chemists the task of isolating a fungicidal agent with which to treat the cord plies of all their belts, to protect them from the ravages of mildew infection. After long months of experiment this was done. The next task was to give the fungicidal agent a thorough test, in all operating conditions and on all types of belting. This, too, required many months of patient work by the Goodyear scientists; but, here again success crowned their efforts. It was proved conclusively that the new fungus-defying agent was completely effective in all circumstances. Since then, every Goodyear belt has been impregnated with this inhibiting agent as a normal part of production routine. As a result, every Goodyear belt installation is impervious to attack by mildew, and can be relied upon to give long trouble-free service.

ANOTHER OF NATURE'S HOSTILE FORCES HAS BEEN CONQUERED BY
GOODYEAR
INDUSTRIAL RUBBER PRODUCTS